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THE DEVELOPMENT OF A PRECISION SERIES OF
LANDOLT RING ACUITY SLIDES

Ailene Morris and James E. Goodson



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THE DEVELOPMENT OF A PRECISION SERIES OF LANDOLT RING ACUITY SLIDES

Ailene Morris and James E. Goodson

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SUMMARY PAGE

THE PROBLEM

The need for the development of improved methodologies for the assessment of the visual capabilities of naval aviation personnel has led to the development of the NAMRL Vision Test Battery. Test stimuli were not available which could meet the requirements for these visual measurements. The problem addressed within this report is the specification, production, duplication and implementation of a series of high resolution test targets adequate to perform this task.

THE FINDINGS

Alternative methods of presenting visual test stimuli were investigated. Optical projection was chosen over hard copy charts or CRT displays. The Landolt ring was selected as the primary stimulus pattern in agreement with the International Ophthalmological Congress of 1909. Projection slide series with geometric progression in size were specified and produced under rigorous quality control. In order to facilitate correct use of the target series, a systematic nomenclature, conversion tables, nomographs and instructions for their use were developed. The slides have been designated the Morris-Goodson series.

RECOMMENDATION

It is recommended that the Morris-Goodson series of precision Landolt rings be considered for use where refined, quantitative measures of visual resolution are required.

ACKNOWLEDGMENTS

The authors would like to thank Robert Barrett and Jim Paul of Visual Aids Service, NAMRL, for their valuable assistance in reproducing the large number of photographic slides. Ralph McNeely and Gerald Arnerman of Micrometrology Laboratories, Dallas, Texas, made important contributions through their meticulous work in developing the master plates and assisting in developing procedures and controls for their reproduction.

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INTRODUCTION

The Vision Test Battery program at the Naval Aerospace Medical Research Laboratory (NAMRL)¹ required the development of capabilities for efficiently and reliably assessing both the central and peripheral visual acuity at near and far distances over a wide range of contrasts and illumination levels. The large, uniform visual field necessary for central and peripheral testing, as well as the range of illumination levels, precluded the use of video or CRT display modes. The most commonly used test configuration for assessing visual acuity incorporates a graduated array of letters such as those seen in the Snellen wall charts. These black-on-white printed production charts are limited in variety, range of target sizes and interval size between lines. The limited variations are frequently memorized, which cancels the value of the test. Further, a generally useful range of sizes is frequently obtained at the expense of small step intervals necessary for sensitive testing.

The test target solution for the Vision Test Battery was to produce projected images through a complex optical system of slide projectors focused at appropriate locations on wide, arc tangent screens placed at far and near distances from the test subject. For this optical system, acuity-resolution targets covering a wide range of sizes with small step intervals were required. The targets had to be of precise size specifications, some of which were extremely small, and had to be exactly reproduced in quantity where multiples were required. Sensitive, reliable visual threshold determinations were needed where slight differences in acuity are important.

The visual acuity test pattern of choice was the Landolt C ring which could be presented with the gap in various orientations providing an objective percent correct score in quantitative data collection.

Photographic film targets were originally produced at NAMRL through standard enlargement and reduction procedures. Possible size range and quality control were limited. The sizes achieved were not precise enough and some deterioration of the film occurred with long-term use. It was decided that a more precise target system was required. A thorough survey of various research laboratories, published literature and commercial resources revealed that visual acuity target slides of the required specifications were not available.

This report describes the development of a series of precision Landolt ring acuity slides. This development required (a) the generation of a series of projection slide targets of exact specifications in size, range of sizes, and pattern characteristics, (b) the development of a systematic nomenclature of specifying precision C visual acuity target sizes, and (c) the development of tables, nomographs and instructions for the utilization of these targets.

An optical equipment manufacturer producing high resolution reticles for sophisticated optical systems was contracted to generate a new series of precision target slides of photoemulsion on glass. These targets were used by NAMRL as masters for duplicating the many slides required in the test program and have proven to be highly satisfactory.

In the process of performing this work a systematic nomenclature was developed for specification of size. New equipment and procedures were developed at the NAMRL Photo Lab for the reproduction and quality control of the duplicate plates. Computer handling of the target size selection, presentation and data analysis were greatly facilitated by the universal size specification system. Nomographs and instructions for the utilization of this new target system in other applications should conserve many man-hours of effort in similar visual research studies or testing programs.

PROCEDURE

The procedure in the development of the new visual acuity target system was (1) decide on the stimulus to be employed throughout the tests, (2) attempt to procure the patterns commercially, (3) produce and evaluate photographic film-in-glass slide series, (4) locate a supplier and contract for the manufacture of precision high resolution plates to be used as masters for duplication, (5) reproduce in quantity, the required precision acuity test slides, (6) develop a systematic nomenclature for specification of target size which would facilitate communication about the targets as well as computer handling and data analysis, (7) arrange in carousel trays target slides with size and orientation compatible with computer control programs, and (8) prepare nomographs and associated instructions for using the target system in other applications.

TEST TARGET SELECTION

Typical visual acuity testing involves wall charts or projections containing various letters of graded sizes which the test subject must resolve and read to the best of his visual capability. However, once these letters are read, they could be memorized and subsequent repetitions would not provide objective results. Charts can be changes and letters rearranged, but quantitative data are difficult to collect. This problem has been solved through the use of symmetrical targets such as a pair of lines, a series of light and dark bars of selected letters such as H, U, E or C. These patterns can be presented in various orientations to confirm the fact that the subject has visually resolved the critical detail. He is asked to report whether the pair of lines or series of bars are aligned horizontally or vertically. Correct letter orientation response is similarly used as evidence that the subject has resolved the elements of the test target.

"The Landolt ring or C was established as the official standard by the International Ophthalmological Congress in 1909."² Standard format of the Landolt C has been defined. The outside diameter is five times the thickness of the ring. The width of the gap and the thickness of the ring are equal. Target size specifications refer to the size of the gap, since this is the critical element to be resolved. The gap opening may be oriented to the right, down, left or up and the subject is required to identify the position of the break. Geometric progression in size change of letters for acuity testing was recommended in the "Report on International Nomenclature for Designating Visual Acuity", in 1953.³

The Landolt C was selected as the acuity target pattern throughout the various tests of the Vision Test Battery program. Psychophysical investigations into visual acuity phenomena require targets that are perfectly formed, precisely sized and, in the use of projection slides, exactly centered to permit superposition of successive targets. For fine acuity determinations the step interval between sizes must be small and regularly spaced. The use of multiple projector displays requires a great number of slides, all perfectly matched. Such a target series was not commercially available.

RESULTS AND DISCUSSION

DEVELOPMENT OF PRECISION LANDOLT C VISUAL ACUITY SLIDES

Specifications and requirements for the high resolution Landolt C visual acuity target slides were prepared for contract fabrication as follows:

High Resolution Landolt C Visual Acuity Target Slides,

Specifications and Requirements*

Pattern Size and Proportions: The standard visual acuity target Landolt C is proportioned with the total size or outside diameter being five times the width of the bar or gap opening. All dimensions of the C pattern are to be within one percent (1%) of specified sizes and 5:1 ratio proportion. See Figure 1.

Rounding Corners: a) Where gap size is less than 0.4mm the maximum radius of corner rounding allowed will be 0.001 mm (1 micron); and b) if gap is more than 0.4 mm the maximum radius allowed will be 0.025mm. See Figure 2.

*From contract proposal by Morris, NAMRL, July 1978.

FIGURE 1
LANDOLT C PATTERN PROPORTIONS

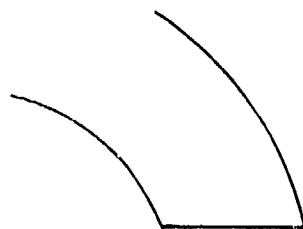
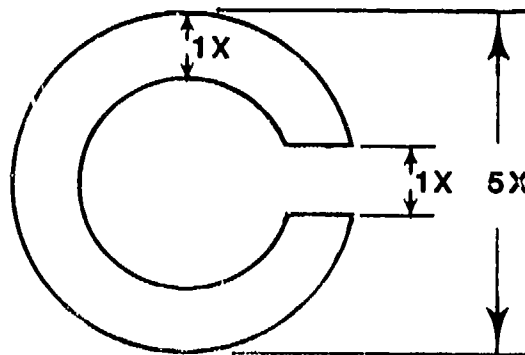


FIGURE 2
RADIUS OF
ROUNDING CORNER

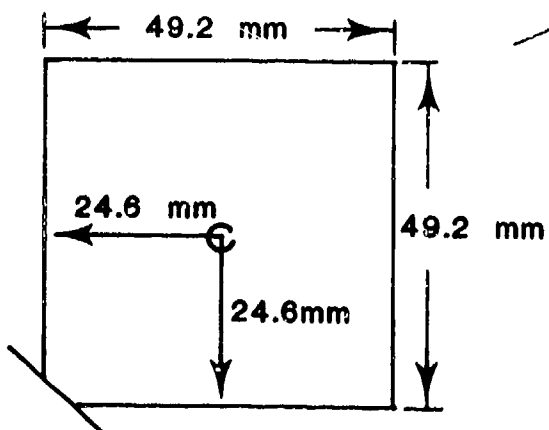
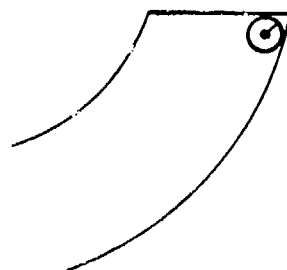


FIGURE 3
CENTERING AND
INDEXING SLIDES

Centering on Slide: Center of C target is to be within plus or minus 0.025 mm of center of plate. Glass plates vary slightly in outside size. Centering halfway across the plate will not produce precisely superimposed images from plate to plate. Target centering will be determined from one corner. Reference corner of plate is to be chamfered off 5 mm or etched for identification and centering. If lower left corner is bevelled with bottom and left edges of glass as reference surfaces, the center of the target should be placed 24.6 mm from each of these references within plus or minus 0.02 mm. See Figure 3.

Target Gap Orientation: There will be four targets of each size. The gap orientations will be changed relative to the reference-centering corner. The four targets in each size will have gap openings pointing to the right, down, left and up direction. (0°, 90°, 180°, and 270°).

Target Sizes: Target sizes will be specified in terms of the unit size, the unit being the height of the C gap and the width of the bar. Total C target diameter will be five times this unit.

Sizes will be specified in the nomenclature of the USAF 1951 resolution target in line pairs per millimeter, LP/mm. The width of a single line is equivalent to the bar or gap of the Landolt C. As in the USAF target, the step interval between target sizes will follow a geometric progression based on the sixth root of 2; i.e., targets double in size every sixth target. See table of target sizes, Table I.

Target Size Range: Target sizes range from the largest with 7.1272 mm gap (equivalent to Group -4, Element size number 2 or 0.070 LP/mm)* to the smallest with 0.00438 mm gap (equivalent to Group 6, Element size number 6 or 114 LP/mm). See table of sizes, Table I.

Number of Targets: Ten Group numbers with six element sizes each, $10 \times 6 = 60$ sizes, plus Group -4 with 5 sizes. Total number of sizes = 65. Four gap orientations each size $65 \times 4 = 260$ targets in one complete set.

Material: Pin-hole free metallic film vacuum evaporated on optical quality or high resolution photoemulsion on glass, as requested. Standard 2" x 2" projection slides, mounted in metal frames.

*The largest target in the table, -4/1 with 8 mm gap would have an outside diameter of 40 mm and is too large for the 38 mm slide frame.

TABLE I

**MORRIS-GOODSON SERIES OF
PRECISION LANDOLT C VISUAL ACUITY TARGET SLIDES**

USAF 1951 Resolution Test Nomenclature			Equivalent Size Line Width or C Target Gap in Millimeters	USAF 1951 Resolution Test Nomenclature			Equivalent Size Line Width or C Target Gap in Millimeters
Group Number	Element Number	Line Pairs per Millimeter		Group Number	Element Number	Line Pairs per Millimeter	
-4	1	0.06250	8.0000	1	1	2.0000	0.2500
	2	.07015	7.1272		2	2.2449	.2227
	3	.07875	6.3496		3	2.5198	.1984
	4	.08839	5.6569		4	2.8284	.1768
	5	.09921	5.0397		5	3.1748	.1575
	6	.1114	4.4898		6	3.5636	.1403
-3	1	.1250	4.0000	2	1	4.0000	.12500
	2	.1403	3.5636		2	4.4898	.11140
	3	.1575	3.1748		3	5.0397	.09921
	4	.1768	2.8284		4	5.6568	.08839
	5	.1984	2.5198		5	6.3496	.07874
	6	.2227	2.2449		6	7.1272	.07015
-2	1	.2500	2.0000	3	1	8.0000	.06250
	2	.2806	1.7818		2	8.9797	.05568
	3	.3150	1.5874		3	10.0794	.04961
	4	.3536	1.4142		4	11.3137	.04419
	5	.3969	1.2599		5	12.6992	.03937
	6	.4454	1.1225		6	14.2544	.03508
-1	1	.5000	1.0000	4	1	16.0000	.03125
	2	.5612	.8909		2	17.9594	.02784
	3	.6300	.7937		3	20.1587	.02480
	4	.7071	.7071		4	22.6274	.02210
	5	.7937	.6300		5	25.3984	.01969
	6	.8909	.5612		6	28.5038	.01754
0	1	1.0000	.5000	5	1	32.0000	.01563
	2	1.1225	.4454		2	35.9188	.01392
	3	1.2599	.3969		3	40.3175	.01240
	4	1.4142	.3536		4	45.2548	.01105
	5	1.5874	.3150		5	50.7968	.009843
	6	1.7818	.2806		6	57.0175	.008769
				6	1	64.0000	.007813
					2	71.8376	.006960
					3	80.6349	.006201
					4	90.5097	.005524
					5	101.5937	.004921
					6	114.0350	.004385

Density: Transparent areas to be no more than 0.05 maximum density (89% transmission). Opaque areas to be at least 3.5 minimum density (0.03% transmission). Minimal opaque correction fluid allowed.

Labels: Each slide should be labelled under the frame in the upper left 'thumb' corner (as seen from rear of projector, facing screen). Label to indicate Group and Element size plus target orientation as centered and aligned; i.e., 1-1R, 1-1D, 1-1L, 1-1G; 1-2R, 1-2D, 1-2L, etc.

Blanks: For calibration purposes provide six framed blanks of slide mounting material identical to the background of each slide set whether transparent or blank. These blanks should be processed along with the target slides so their transparency, opacity, glass quality, thickness or other characteristics can be reliably used as indicators of target slide characteristics.

NOTE: Inspection for flaws, check of centering alignment and precise size measurements to confirm target acceptability will be carried out on a greatly enlarged projected image.

The above specifications and requirements were submitted to various optical equipment manufacturers and a contract was let to Micrometrology Laboratories of Dallas, Texas. By means of modern engineering techniques, the contractor prepared machine-produced master drawings of the target pattern which were up to 400-times the size of the finished product. Working at this size, extremely precise control over detail and quality was achieved. The first plates were made with evaporated metallic film coating; however, for the smallest size targets the metal grain size was almost larger than the required target gap size. It was determined that the optimum material for the acuity target plates was Kodak high resolution photo emulsion on precision flat glass with anti-halation backing, Type 1A. With extreme reduction technology, photoprojection duplication, chemical reversal in the photodevelopment process, and high quality substrate materials, master targets were produced in the wide range of sizes required. The complete series includes Landolt rings with sixty-five gap sizes ranging from 7.127 to 0.00438 millimeters, as measured under high power image magnification.

The master target plates provided by the contractor were duplicated in quantity by the NAMRL Visual Aids Services photographic facility. To maintain accurate centering a special jig tool was devised to adapt a contact printer to hold and press the precision flat glass plates. In order to reproduce the high quality slides, special air, temperature, lighting control and processing procedures were developed. The slides were microscopically inspected for flaws, measured for required density, then double-checked for centering and exact specified size. Over

nine-thousand copies have been produced which closely fulfill the specified requirements laid down for the original master targets. The Vision Test target tray assemblies have been prepared from the resulting supply bank of slide duplicates.

SYSTEMATIC NOMENCLATURE FOR ACUITY TARGETS

Communication with optical engineers and reticle manufacturers concerning acuity target slides was greatly facilitated by the use of their standard resolution test nomenclature. Quality and function of optical systems as well as photographic processes are commonly evaluated through the use of USAF 1951 Resolving Power Targets⁴ (See Fig. 4). The general use of these targets and their nomenclature has resulted in a terminology, an assessment procedure and standardized numerical values which provide universally understood tolerances or resolution characteristics of any optical system. Briefly, the procedure involves reading a resolution test pattern of line pairs which change in size by the sixth root of two; i.e., in every sixth target the number of lines is doubled (See Table II). Resolution is expressed as the number of line pairs per millimeter. The term "line pair" refers to a light and dark bar. In each pattern there are three light and two dark bars. There are two patterns set at right angles to form a resolution element. The width of the single lines are equal to the spaces and the line length is five times its width. Six elements are called a Group. The Group number is the power of two to which the first element in the Group is raised to identify the number of lines in that element. For example, for Group 4-Element 1, two to the fourth power (2^4) is 16 lines per millimeter. (See Table II).

The optical resolution test nomenclature was adapted for use with visual acuity measures. In Table I, the line pairs per millimeter have been converted to equivalent size of line width or gap in the Landolt "C" acuity test pattern. This table was used for specifications in the target production contract. The above system of precision visual acuity target slides has been designated Morris-Goodson Series.

Table III illustrates how the Morris-Goodson systematic nomenclature for the precision "C" acuity targets has been employed in the Vision Test Battery (VTB) program. Many duplicate plates were made of each Group and Element size. The "C" gap sizes on the slide is listed in the third column in millimeters. In the following columns target sizes in minutes of visual angle are given for four testing conditions. The VTB optical system consists of slide projectors at far and near distance, and at each distance there are projectors for performing the central and peripheral vision tests. The system of multiple random-access slide projectors and timing shutters is automatically controlled. Each of these projectors has a different image magnification property. In Table I/I, the target with one-half (0.500) millimeter gap is identified as Group 0,

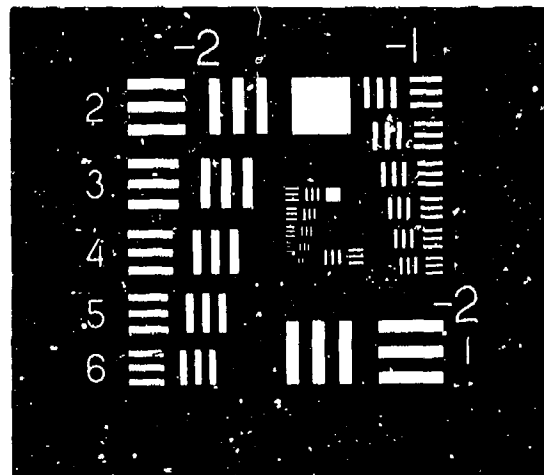


FIGURE 4

USAF 1951 RESOLVING POWER TEST PATTERN

TABLE II

Number of Lines per Millimeter in USAF
Resolving Power Test Target 1951

Element No.	Group Number									
	-2	-1	0	1	2	3	4	5	6	7
1	0.250	0.500	1.00	2.00	4.00	8.00	16.0	32.0	64.0	128.
2	.280	.561	1.12	2.24	4.48	8.96	17.96	36.0	71.8	144.
3	.315	.630	1.26	2.52	5.04	10.1	20.16	40.3	80.6	161.
4	.363	.707	1.41	2.83	5.66	11.3	22.62	46.3	90.6	181.
5	.397	.793	1.58	3.17	6.36	12.7	25.36	50.8	102.	203.
6	.446	.891	1.78	3.56	7.13	14.3	28.61	57.0	114.	228.

TABLE III
MORRIS-GOODSON SERIES PRECISION LANDOLT C SLIDES, VISION TEST BATTERY
CONVERSION TABLE FOR TARGET GAP SIZE

GROUP ELEMENT	SLIDE SIZE MM	IMAGE SIZE - MINUTES VISUAL ANGLE			
		FAR DISTANCE 5500 MM		NEAR DISTANCE 457.2mm	
		CENTRAL 12.2x	PERIPHERAL 16.0x	CENTRAL 5.7x	PERIPHERAL 8.5x
-4	1	8.000000	61.002778	80.002132	342.588576
	2	7.127190	54.347591	71.274461	305.263822
	3	6.349604	48.418407	63.498795	271.996008
	4	5.636854	43.136044	56.571327	242.346971
	5	5.039684	38.429950	50.399557	215.925050
	6	4.489848	34.237267	44.901067	192.380396
-3	1	4.000000	30.501989	40.002420	171.400675
	2	3.563595	27.174220	35.638188	152.707167
	3	3.174802	24.209504	31.750074	136.051235
	4	2.828427	21.568234	28.286142	121.211134
	5	2.519842	19.215125	25.200117	107.989152
	6	2.244924	17.118740	22.450773	96.209029
-2	1	2.000000	15.251070	20.001379	85.713655
	2	1.781797	13.587163	17.819214	76.363001
	3	1.587401	12.104789	15.875122	68.032277
	4	1.414214	10.784144	14.143131	60.610276
	5	1.259921	9.607581	12.600101	53.997906
	6	1.122462	8.559383	11.225416	48.106869
-1	1	1.000000	7.625544	10.000711	42.858493
	2	0.890899	6.793588	8.903622	38.182678
	3	0.793701	6.052397	7.937572	34.016971
	4	0.707107	5.392075	7.071573	30.305727
	5	0.629961	4.803793	6.300056	26.999369
	6	0.561231	4.279693	5.612712	24.053729
0	1	0.500000	3.812773	5.000358	21.429454
	2	0.445449	3.396795	4.454813	19.091486
	3	0.396850	3.026200	3.968787	17.008590
	4	0.353553	2.696038	3.535787	15.152937
	5	0.314980	2.401897	3.150029	13.499737
	6	0.280616	2.139847	2.806356	12.026901
1	1	0.250000	1.906387	2.500179	10.714753
	2	0.222725	1.698398	2.227407	9.545762
	3	0.198425	1.513100	1.984394	8.504308
	4	0.176777	1.348019	1.767894	7.576478
	5	0.157490	1.200948	1.575014	6.749875
	6	0.140308	1.069923	1.403178	6.013455
2	1	0.125000	0.953193	1.250090	5.357380
	2	0.111362	0.849199	1.113703	4.772883
	3	0.099213	0.756550	0.992197	4.252156
	4	0.088388	0.674010	0.883947	3.788240
	5	0.078745	0.600474	0.787507	3.374538
	6	0.070154	0.534962	0.701589	3.006728
3	1	0.062500	0.476597	0.625045	2.678690
	2	0.055681	0.424599	0.556852	2.386442
	3	0.049606	0.378275	0.496098	2.126078
	4	0.044194	0.337005	0.441973	1.894120
	5	0.039373	0.300237	0.393754	1.687469
	6	0.035077	0.267481	0.350795	1.503364
4	1	0.031250	0.238298	0.312522	1.339345
	2	0.027841	0.212300	0.278426	1.193221
	3	0.024803	0.189138	0.248049	1.063039
	4	0.022097	0.168502	0.220987	0.947060
	5	0.019386	0.150119	0.196877	0.843735
	6	0.017538	0.133740	0.175397	0.751682
5	1	0.015625	0.119149	0.156261	0.669673
	2	0.013920	0.106150	0.139213	0.596610
	3	0.012402	0.094569	0.124025	0.531520
	4	0.011049	0.084251	0.110493	0.473530
	5	0.009843	0.075059	0.098438	0.421867
	6	0.008769	0.066870	0.087699	0.375841
6	1	0.007813	0.059575	0.078131	0.334830
	2	0.006960	0.053075	0.069606	0.298305
	3	0.006201	0.047284	0.062012	0.265760
	4	0.005524	0.042126	0.055247	0.236765
	5	0.004922	0.037530	0.049219	0.210934
	6	0.004385	0.033435	0.043849	0.187921

Element 1. When presented on the far screen for the central acuity test, the gap will subtend 3.8 minutes visual angle (mva) at the test subject's eyes and for the peripheral test it would subtend 5.0 mva. For the near test distance the central and peripheral configurations would be 21.4 and 31.9 mva, respectively.

Using an 80-slot carousel slide tray with four "C" orientations at each size permits the presentation of twenty target sizes per tray. Selecting the range of those twenty sizes allows for acuity measurements under a wide range of conditions; far or near, central or peripheral retinal locations, or high or low target-to-background contrast. The ten boxes drawn on Table III enclose the target sizes included in the successive, overlapping test trays. For one test, a wider range of sizes was required. Every third size target was selected from the original series, thus giving coarse step-intervals, while including the full range of sizes necessary to perform the test.

Table IV provides another example of how the target series was used in the Dynamic Visual Acuity test. The same plates have been installed in the fixed magazines of a rotating projector with different projection and observing distances, plus new visual performance demands. The one-half millimeter gap slide (Group 0, Element 1) now subtends 14.5 minutes visual angle and appears in the scoping trays and two target trays in the overlapping size sequence. In this test the target rotational velocity is varied, thus requiring progressively larger "C" targets for successful visual resolution and, therefore, a wide range of sizes.

APPLICATIONS

Selecting Target Slide Sizes

The sequence of ten overlapping target tray series used in the various projectors of the Vision Test Battery optical system permits acuity testing from 71.7 to 0.168 minutes visual angle. The target range selected for each tray effectively covers observing conditions of far or near test distance, central or peripheral retinal location and high or low target contrast.

Given the approximate visual acuity to be measured and, knowing the image magnification factor of the particular testing set-up, one can determine which specific target sizes should be chosen for quantitative testing.

Assume the visual acuity to be measured is expected to be around 20/20 Snellen fraction (1 mva) or better. From Table III, the Far Central Acuity test with 12.2x magnification and the tray with targets containing Group 2 would give the necessary acuity range from 1.5 to 0.168 minutes visual angle.

TABLE IV

MORRIS-GOODSON PRECISIONS LANDOLT C TARGET SERIES FOR THE DYNAMIC VISUAL ACUITY TEST

EYE DISTANCE 4 FT (1219.2MM)
MAGNIFICATION FACTOR 10.3

GROUP	TARGET				< SCOPING TRAYS >										< TEST TRAYS >											
	SIZE	CM	LG	SM	-3	-3/4	-2	-2/4	-1	-1/4	0	0/4	1	1/4	2	2/4	3	3/4	4	4/4	5	5/4	6			
-3	116	159	223	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
-2	58	87	121	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7			
-1	29	42	55	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13			
0	14	21	28	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19			
1	7	10	14	18	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25			
2	3	4	6	8	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12			
3	1	2	3	4	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6			
4	0	1	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4			
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			

Determining Size Magnification of Projected Targets

Knowing the expected visual acuity range to be measured and the available target size series, one can calculate what the image size magnification must be to use them. By adjusting projection distance and/or changing the focal length of the lens, then measuring the resultant image, the desired optical set-up can be established.

A calibration reticle slide is then used to measure the screen image size for each test condition. The slide is a contact copy of a high resolution millimeter scale with fine divisions. The millimeter slide is installed in the projectors and displayed on the target screen in the exact position of the target slides. A piece of millimeter grid paper is held against the screen and slipped into the projected slide image area. By reading on the grid paper how many millimeters the enlarged, projected slide image covers, a magnification factor may be determined. In other words, if one millimeter of the reticle in the slide gate becomes 10 millimeters on the screen, the magnification factor is ten times (10x). The slide-to-screen magnification factor calculated from these measurements includes all size change, whether due to lens focal length, condensing lens optics or the spreading light rays of projection distance.

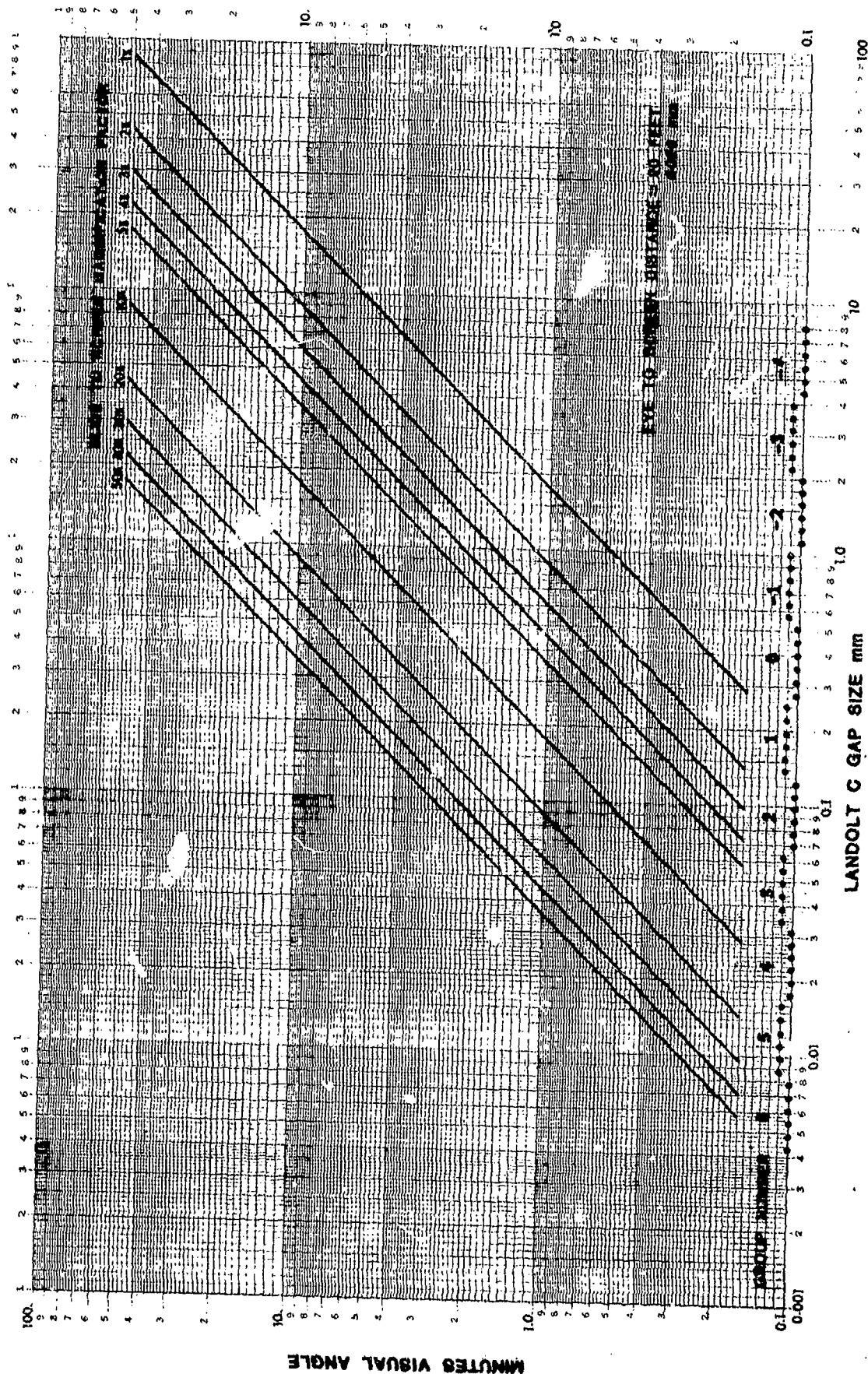
Conversion Nomograph for Precision Target Series

A nomograph has been prepared for far visual acuity testing at 20-foot range, Figure 5. The precision series of target sizes in millimeters have been plotted along the abscissa and angular size is indicated on the ordinate of the Log-Log plot. Conversion diagonal lines for various magnification factors have been drawn at the appropriate locations. At 6096 millimeters (20 feet) range a one minute visual angle (mva) target would have to measure 1.77 millimeters on the far screen and a one millimeter screen image would subtend 0.5639 mva. If there were no change in size from slide to screen the conversion line would be the one-times (1x) magnification factor plotted at 0.5639 mva. By simple multiplication, various size increments have been illustrated for magnification factors of two-times (2x), ten-times (10x), etc..

Assume the far visual acuity level to be assessed is approximately 20/20 or one minute visual angle target resolved. Also assume targets of Group 1 size (0.25 mm gap) and smaller are available. On the nomograph find the intersection of one minute visual angle and the 0.25 target size. A ten times (10x) size magnification would put these targets in the desired angular size range. This magnification can be achieved by proper selection of lens and projection distance.

On the other hand, with the acuity conditions defined above i.e., 20/20 far visual acuity, plus a 10x size magnification of the optical system, one can derive what size range of targets

FIGURE 5 CONVERSION NOMOGRAPH FOR THE MORRIS-GOODSON PRECISION ACUITY TARGET SERIES



would be required for testing. At the intersection of one minute visual angle and the 10x magnification diagonal line, drop down to the baseline to read target size 0.177 mm which is a Group 1 Element 4 target. The testing series should then include targets around this size and smaller.

The use of this conversion nomograph readily permits the selection of appropriate magnification factors required, correct target series or, if target size and magnification are known, derive target angular size estimates. Exact values would be measured or calculated where needed.

Morris-Goodson Precision Target Series

Target slides prepared according to the Morris-Goodson Precision Series designation have been used by us extensively in threshold testing. The geometric size progression is highly satisfactory for the psychophysical functions assessed. For refined measures, as are required with the superior acuity of directly fixated, high contrast targets under high illumination, there are small targets with very small step size intervals. For reduced visual conditions, such as with low contrast, off-center location or low illumination levels, the large targets are spaced with larger step sizes appropriately. Figure 6 presents psychophysical threshold curves for five far visual acuity tests on one subject in the Vision Test Battery program at NAMRL. The complete range of far test trays with sizes from 71 to 0.16 mva were involved in these tests.

An important additional advantage of this system of target sizes is in programming computer control for automatic target selectio. and data processing.⁵ Because the target sizes are not individually variable, but spaced in a regular progression, it is not necessary to store and identify each target size. In the automated series of the Vision Test Battery, the largest target in a tray series is entered while setting up each test. The computer program applies the geometric progression formula on-line and calculates exact sizes in the decreasing sequence that follows as the test proceeds.

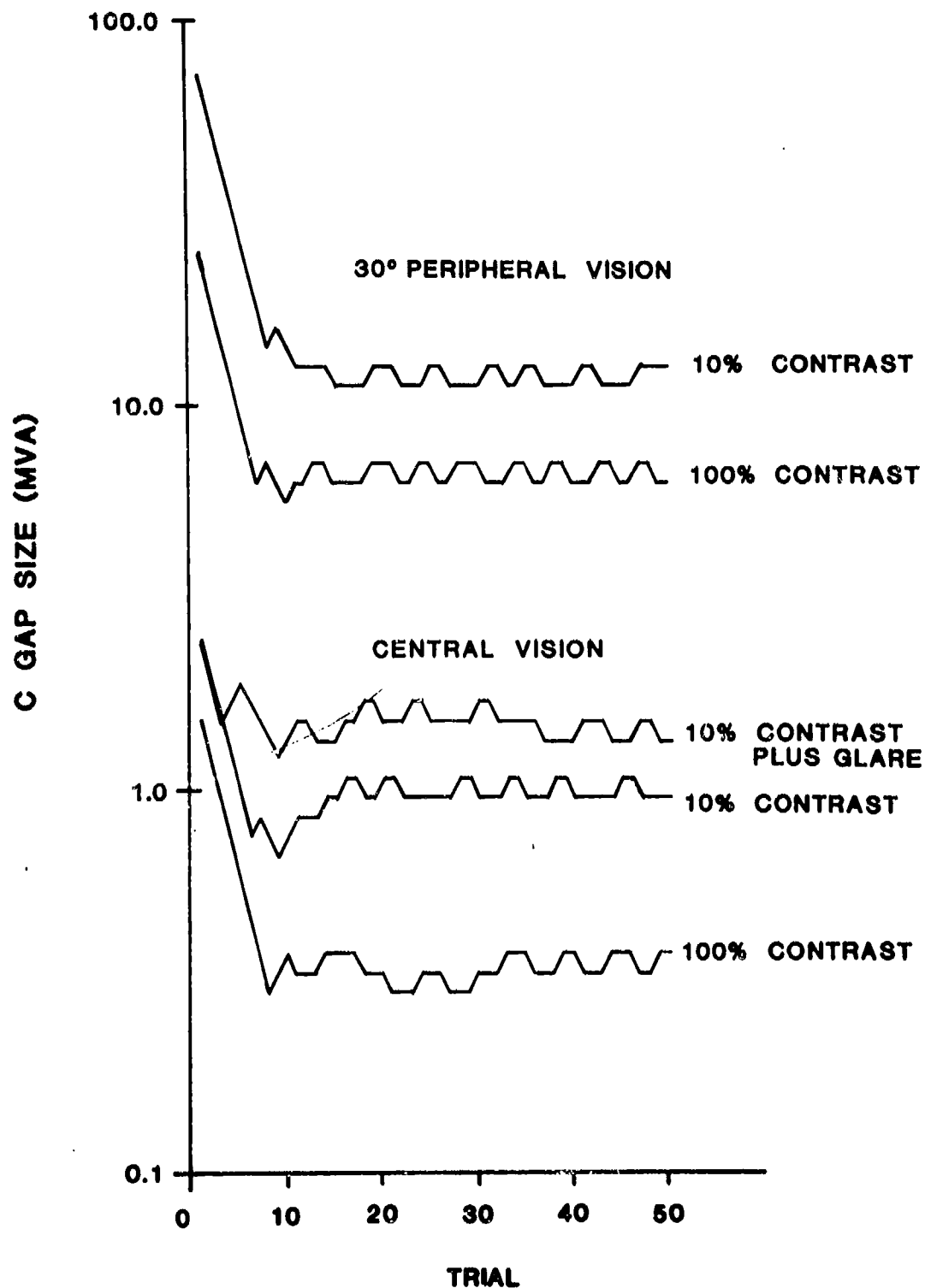
The geometric size progression and systematic nomenclature of the Morris-Goodson Precision Target Series for visual testing has been demonstrated to be useful and versatile.

SUMMARY

This report has addressed how precision target slides for quantitative visual measurement were specified, reproduced and used. This target series with fine, progressively spaced size sequences now permits refined, quantitative, repeatable psychophysical measures of visual performance heretofore unavailable. Systematic nomenclature for describing and handling the targets series has been developed. A conversion nomograph was devised to

FIGURE 6

FAR VISUAL ACUITY TESTS- VISION TEST BATTERY



expedite the use of the targets and their integration with required optical systems. Examples of the application of the new target system and nomograph have been presented.

Ongoing research and extensive testing at NAMRL have demonstrated the utility and feasibility of the Morris-Goodson Precision Target Series system and nomenclature. The system has universal application in quantitative vision testing and provides a standardized basis for target specification and communication. It is recommended that the Morris-Goodson Precision Target Series system be considered for use where refined, quantitative measures of vision are required.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The need for the development of improved methodologies for the assessment of the visual capabilities of naval aviation personnel has led to the develop- ment of the NAMRI Vision Test Battery. Test stimuli were not available which could meet the requirements for these visual measurements. The problem addressed within this report is the specification, production, duplication, and implementation of a series of high resolution test targets adequate to perform this task.		

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20. ABSTRACT (continued)

Alternative methods of presenting visual test stimuli were investigated. Optical projection was chosen over hard copy charts of CRT displays. The Landolt ring was selected as the primary stimulus pattern in agreement with the International Ophthalmological Congress of 1909. Projection slide series with geometric progression in size were specified and produced under rigorous quality control. In order to facilitate correct use of the target series, a systematic nomenclature, conversion tables, nomographs and instructions for their use were developed. The slides have been designated the Morris-Goodson series.

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